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EFFECT OF SOIL MOISTURE AND NITROGEN FERTILIZATION ON THE VEGETATIVE GROWTH AND CHEMICAL COMPOSITION OF BERMUDAGRASS (*Cynodon dactylon* L.)

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ABSTRACT

This study was carried out in the open Experimental Field of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, during the two successive seasons of 1996/1997 and 1997/1998, with the aim of investigating the effect of soil moisture content [irrigation when soil moisture content reached 30, 50 or 70% of field capacity (F.C.)], and N fertilization levels [0, 5, 10 or 15 gm N/m^2, applied monthly using ammonium sulphate (20.5% N)] on the vegetative growth and chemical composition of Bermudagrass (*Cynodon dactylon* L.) plants. At each irrigation, the plants were watered with 25 litres of tap water/m^2.

The following results could be obtained:

Irrigation when the soil moisture content reaches 70% F.C., combined with application of a relatively high N fertilization rate (15 g N/m^2), resulted in the most vigorous vegetative growth (in terms of plant height, as well as the fresh and dry weight of clippings). However, turf colour was more sensitive to the N rate than to the soil moisture level (within the tested range of soil moisture levels), since the best colour (i.e. the highest leaf pigments content) was obtained with fertilization using a moderate N rate (10 g/m^2), regardless of the soil moisture level. Increasing the soil moisture content caused a steady reduction in the soluble sugars content, but increased the insoluble ones in the clippings. Also, the contents of soluble sugars, insoluble sugars and total carbohydrates were steadily increased by raising the N fertilization rate, with the highest N rate (15 g/m^2) giving the highest values. In most cases, the highest contents of nutrients (N, P and K) were obtained from plants fertilized with the medium N rate (10 g/m^2). The effect of soil moisture on the nutrients content differed from one nutrient to another, since the highest mean concentrations of N, P and K were obtained with irrigation at 30%, 70% and 50% F.C., respectively.

Keywords: turfgrass, Bermudagrass, soil moisture, fertilization.

INTRODUCTION

Bermudagrass (*Cynodon dactylon* L.) is one of the most popular turfgrasses belonging to the Poaceae (Gramineae) family. It is used extensively in the design of landscape projects and sport fields, and is well suited to the Egyptian environmental conditions, especially in areas with mild winter temperatures, such as coastal regions of the Red Sea, where a large scale urban development (including the establishment of new cities and touristic resorts) takes place.

Proper maintenance of the turfgrasses is essential for keeping a healthy lawn appearance. Fertilization and irrigation are among the most important cultural practices needed by turfgrasses. Chemical nitrogenous fertilization is especially important for maintaining vigorous vegetive growth, since the food reserves in turfgrasses are frequently removed by mowing. The importance of nitrogenous fertilization to the growth of different turfgrass species has been investigated by several investigators [Hossni (1993) on *Cynodon dactylon* L., Saleh (1993) on ryegrass, Carrow (1994), on bentgrass, Huang and Petrovic (1995) on *Agrostis palustris*, and Soliman (1997) on ryegrass].

Irrigation is also very important to the growth and development of turfgrasses, since rainfall is usually scarce in most parts of Egypt. Moreover, the high summer temperatures lead to rapid vegetative growth and high evapotranspiration rates, both of which require an efficient irrigation program which ensures that the soil moisture content is kept at a level sufficient for supplying the plants with their water requirements. The effect of different irrigation regimes on the growth and development of turfgrasses has be studied by several researchers [Schmidt and Snyder (1984) on *Agrostis palustris*, Meyer and Gibeault (1987) on hybrid Bermudagrass, Lodge and Lawson (1993) on a mixed sward of *Festuca rubra*, *Agrostis castellana* and *A. capillaris*, McKenney and Zartman (1997) on *Buchloe dactyloides* and *Cynodon dactylon*, and Ruemmele and Amador (1998) on bentgrass].

This study was conducted with the aim of investigating the effect of different soil moisture levels and nitrogenous fertilization treatments on the vegetative growth and chemical composition of Bermudagrass (*Cynodon dactylon* L.).

MATERIALS AND METHODS

This study was carried out in the open Experimental Field of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, during the two successive seasons of 1996/1997 and 1997/1998. The aim of this study was to investigate the effect of irrigation at 3 levels of soil moisture [30, 50 and 70% of field capacity (F.C.)], and 4 levels of nitrogen fertilization (0, 5, 10 and 15 gm N/m^2) on the vegetative growth and chemical composition of Bermudagrass (*Cynodon dactylon* L.) plants.

The soil of the experimental area was well prepared, then divided to square plots (1 × 1 m), which were separated from each other using acrylic sheets placed vertically into the soil to a depth of 35 cm. The mechanical and chemical characteristics of the soil in the experimental area are shown in Table (A).

Seeds of Bermudagrass (*Cynodon dactylon* L.), produced by Genetics International Inc., California, U.S.A., were sown on September 28th, 1996, and germinated after one week. In both seasons, the irrigation and fertilization treatments were started on April 10th, and were terminated on November 10th. The plants were irrigated with 25 litre water/m^2 at the 3 levels of soil moisture content (S.M.C.): 30, 50 and 70% of field capacity. Soil moisture contents were measured using a tensiometer. Chemical composition of the tap-water used for irrigation is shown in Table (B). Under each level of soil moisture, plants were fertilized with ammonium sulphate (20.5% N) at the rates of 0, 5, 10 and 15 gm N/m^2, applied monthly starting from April to October (in both seasons).

Table (A): Physical and chemical characteristics of the soil used for growing Bermudagrass (*Cynodon dactylon* L.) during the 1996/1997 and 1997/1998 seasons..

Partical size distribution (%)			Texture class	$CaCO_3$ (%)	E.C. (mmhos/ cm)	pH
Sand	Silt	Clay				
51	8	41	Sandy-clay	2.4	0.71	7.7

Cations (meq/1)				Anions (meq/1)				Macro-elements (ppm)			Micro-elements (ppm)			
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	N	P	K	Fe	Cu	Zn	Mn
2.9	0.1	2.2	1.3	-	1.2	2.5	2.8	30	79.3	800	15.9	1.52	4	20.4

Table (B): Chemical composition of the tap water used for irrigation of Bermudagrass (*Cynodon dactylon* L.) during the 1996/1997 and 1997/1998 seasons.

pH	E.C. (m mhos/cm)	Cations (meq/1)				Anions (meq/1)				*S.A.R.	S.S. (%)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}		
7.1	0.42	1.8	1.2	1.5	0.18	-	2.2	1.25	1.23	1.23	0.032

* S.A.R. = Sodium adsorption ratio   S.S. = Soluble sodium

The design of this experiment was a split plot design, with 12 treatmenst (3 soil moisture levels X 4 fertilization treatments) and 3 replicates. The main plots were assigned to the irrigation treatments, while the sub-plots were assigned to the fertilization rates. The main plots were arranged in a completely randomized design.

Mowing was started when the plants reached a height of 5 cm before fertilization. In each season, the turfgrass was mowed every 15 days to a height of 2 cm, beginning from April 10th to November 10th (14 cuts per season). The recorded data included plant height (cm) immediately before each mowing, as well as the fresh and dry weights of clippings (g) after each mowing. The dry weight of clipping samples was recorded after drying in an oven at 70° C for 72 hours. Also, dried grass samples were ashed at 600° C in a muffle furance, and the ash content in the dry matter was recorded.

Chemical analysis of the fresh leaf samples was also conducted to determine their contents of pigments (chlorophyll a, b and carotenoids), as mg/g f.w., according to Saric *et al.*, (1967), while dried leaf samples were chemically analyzed to determine their contents of soluble and insoluble sugars (using the method described by Smith *et al.*, 1956). In addition, the nutrients were extracted from dried leaf samples using the wet digestion procedure described by Piper (1947), and the nitrogen content was determined using the micro-Kjeldahl method outlined by Pregl (1945). The phosphorus content was also estimated using the method described by King (1951), while the potassium content was determined using an Atomic Absorption Flame Emission Spectrophotometer (Schimadzu, Model A.A. 646).

A combined analysis of data variance was carried out according to the procedure outlined by Snedecor and Cochrane (1980), and the means were compared using the "new least significant difference (New L.S.D.)" test at the 5% level, as recommended by Waller and Duncan (1969).

RESULTS AND DISCUSSION

I- Vegetative growth

1. Plant height

Results recorded in the two seasons (Table 1) show that significant differences were detected between the heights of Bermudagrass plants irrigated at the three soil moisture levels. In both seasons, plant height was gradually increased as the moisture level increased in the soil. Accordingly, plants irrigated at the highest moisture level (70% F.C.) were significantly taller than those irrigated at the lower soil moisture levels (30% or 50 % F.C.).

Regarding the effect of N fertilization on plant height, the data in Table (1) show that in both seasons, plants supplied with the different fertilization treatments were significantly taller than the unfertilized plants. Moreover, raising the N fertilization rate caused a steady increase in plant height, i.e. the tallest plants were those supplied with the highest N rate (15 g N/m^2). These results are in agreement with those obtained by Hossni (1993) on *Cynodon dactylon* L., Saleh (1993) on ryegrass, Huang and Petrovic (1995) on *Agrostis palustris*, and Soliman (1997) on ryegrass.

Data recorded on the interaction between the irrigation and nitrogen fertilization treatments (Table 1) reveal that the most unfavourable combination of treatments (i.e. giving the shortest plants) was supplying the plants with no fertilization (control) and watering them at the lowest soil moisture level (30% F.C.). On the other hand, the tallest plants were those supplied with the highest fertiliation rate (15 gm N/m^2) and irrigated at the highest moisture level (70% F.C.). It is also clear from the presented data that, in general, increasing the moisture level reduced the demand for nitrogenous fertiliztion needed to give the same plant height as that obtained with relatively high fertilization rates combined with low moisture level. For example, the height of plants irrigated at the lowest soil moisture level (30% F.C.) and supplied with the highest N rate (15 gm) was equal to that of plants irrigated at the medium soil moisture level (50% F.C.) and fertilized with the medium N rate (10 gm), and was nearly equal to that obtained when the lowest N rate (5 gm) was combined with the highest moisture level (irrigation at 70% F.C.).

2. Fresh and dry weights of clippings

Data presented in Table (1) reveal that irrigation at the different soil moisture levels led to significant differences in the fresh and dry weights of clippings.

Table (1): Effect of irrigation and nitrogen fertilization treatments on plant height (cm), and fresh and dry weights of clippings (g/m^2) of *Cynodon dactylon* L. during the 1996/1997 and 1997/1998 seasons.

Fertilization treatments (B)	Plant height (cm)				Fresh weight of clippings (g/m^2)				Dry weight of clippings (g/m^2)			
	Irrigation (A)			Mean (B)	Irrigation (A)			Mean (B)	Irrigation (A)			Mean (B)
	30%	50%	70%		30%	50%	70%		30%	50%	70%	
First season (1997)												
Control	4.01	4.69	4.98	4.56	37.33	50.00	58.11	48.48	16.38	21.27	24.08	20.58
5 g N/m^2	5.78	6.81	7.33	6.64	83.61	110.07	126.57	106.75	35.85	45.83	51.35	44.35
10 g N/m^2	6.80	7.70	8.35	7.62	99.77	128.93	142.54	123.75	42.11	52.87	56.63	50.54
15 g N/m^2	7.70	8.42	8.86	8.33	106.98	136.77	149.36	131.03	43.90	54.35	57.54	51.93
Mean (A)	6.07	6.91	7.38	---	81.92	106.44	119.14	---	34.56	43.58	47.40	---
New L.S.D. (0.05)												
A		0.048				3.13				1.31		
B		0.045				3.43				1.44		
A X B		0.080				5.97				2.50		
Second season (1998)												
Control	3.80	4.60	4.93	4.44	32.31	45.99	53.91	44.07	14.05	19.43	22.07	18.52
5 g N/m2	5.63	6.76	7.26	6.55	77.47	102.94	120.31	100.24	32.68	42.23	48.15	41.02
10 g N/m2	6.63	7.62	8.27	7.51	92.28	116.36	136.52	115.05	37.99	46.54	53.03	45.85
15 g N/m2	7.620	8.34	8.99	8.31	98.26	125.49	143.20	122.32	38.94	48.49	53.79	47.07
Mean (A)	5.92	6.83	7.36	---	75.08	97.69	113.48	---	30.91	39.17	44.26	---
New L.S.D. (0.05)												
A		0.025				2.76				1.13		
B		0.043				3.09				1.27		
A X B		0.076				5.37				2.21		

In both seasons, the values recorded for these two parameters showed steady increases with increasing the soil moisture level, with plants irrigated at the highest soil moisture content (70% F.C.) giving significantly higher values than those irrigated at the lower soil moisture levels (30 or 50% F.C.). These results coincided with the findings of Schmidt and Snyder (1984), who concluded that growing *Agrostis palustris* under low soil moisture tended to reduce foliage yields.

The results recorded in the two seasons (Table, 1) show also that plants receiving the different fertilization treatments gave significantly heavier fresh and dry weights of clippings, compared to those obtained from unfertilized control plants. Even the lowest N fertilization rate (5 g N/m^2) gave values that were more than double those of the control (in both seasons). A similar promoting effect of N fertilizer on clippings yield was reported by Carrow (1994), on bentgrass, and Soliman (1997) on ryegrass. They concluded that nitrogen fertilizer treatments increased plants fresh weight over untreated plants. Moreover, raising the N fertilization rate resulted in steady increases in the fresh and dry weights of clippings, with the highest fertilization rate (15 g/m^2) giving the highest mean values in both seasons. The increase in fresh weight of clippings was significant when the N rate was increased from 5 to 10 g/m^2 or from 10 to 15 g/m^2. Similarly, the dry weight of clippings was increased significantly when the N rate was increased from 5 to 10 g/m^2, but when the N rate was increased from 10 to 15 g/m^2, the increase in dry weight was insignificant. These results are in agreement with those obtained by Hossni (1993) on *Cynodon dacytlon*, Saleh (1993) on ryegrass, and YuFen and JiXiong (1994) on *Poa pratensis*.

Regarding the interaction between irrigation levels and fertilization treatments, the recorded data (Table, 1) show that plants grown under low levels of soil moisture (irrigation at 30% F.C.) and nitrogenous fertilization (control) gave the lowest fresh and dry weights of clippings. Raising the soil moisture level and/or the N fertilization level resulted in steady increases in the recorded values. Accordingly, plants supplied with the highest levels of soil moisture (irrigation at 70% F.C.) and fertilization (15 g N/m^2) gave the heaviest fresh and dry weights of clippings. Within each soil moisture level, any increase in N fertilization rate caused a significant increase in the clippings fresh weight. Also, within each N fertilization level, any increase in soil moisture level caused a significant increase in clippings fresh weight. In most cases, the response of clippings dry weight to changes in soil moisture or N fertilization levels was similar to that of clippings fresh weight. The only exception to this general trend was observed with increasing the N fertilization level from 10 to 15 g N/m^2 (regardless the soil moisture level), which led to insignificant increases in clippings dry weight.

II. Chemical composition

1. Ash content

Data in Table (2) reveal that although the mean ash contents obtained with the different irrigation treatments appear to be almost similar, the differences between the recorded values were statistically significant. Moreover, the ash content increased steadily as the irrigation level increased, with the highest soil moisture level (irrigation at 70% F.C.) giving the highest mean values in both seasons.

The results recorded in the two seasons show also that the different N fertilization treatments resulted in significant increases in the ash content, compared to that of unfertilized control plants. Among the different fertilization treatments, supplying the plants with the medium N rate (10 g N/m2) gave the highest mean values in both seasons, followed by the highest N rate (15 g N/m^2), whereas the lowest N fertilization rate (5 g N/m^2) was the least effective one (in terms of increasing the ash content).

The different combinations of irrigation and fertilization treatments also had a significant effect on the ash content. In both seasons, unfertilized plants grown at the lowest soil moisture level (irrigation at 30% F.C.) had the lowest ash content, whereas the highest value was obtained from plants grown at the highest moisture level (irrigation at 70% F.C.), and fertilized with the medium N rate (10 g N/m^2).

Table (2): Effect of irrigation and nitrogen fertilization treatments on the ash content of *Cynodon dactylon* L. clippings during the 1996/1997 and 1997/1998 seasons.

Fertilization treatments (B)	Ash content (% of dry matter)							
	First season (1997)				Second season (1998)			
	Irrigation (A)			Mean (B)	Irrigation (A)			Mean (B)
	30%	50%	70%		30%	50%	70%	
Control	9.71	9.96	10.23	9.97	9.58	9.88	10.14	9.87
5 g N/m^2	10.04	10.33	10.55	10.31	9.92	10.19	10.35	10.15
10 g N/m^2	10.59	10.90	11.19	10.89	10.49	10.81	11.07	10.79
15 g N/m^2	10.37	10.61	10.78	10.59	10.32	10.57	10.72	10.54
Mean (A)	10.18	10.45	10.69	---	10.08	10.36	10.57	---
New L.S.D. (0.05)								
A	0.012				0.008			
B	0.012				0.009			
A X B	0.021				0.017			

2. Leaf pigments content

a. Chlorophylls [a, b and total chlorophyll (a+b)] content

Data presented in Table (3) show that in both seasons, the chlorophylls content was increased steadily as the soil moisture level was increased (with irrigation at 30%, 50% or 70% F.C.). However, in many cases the increases recorded in the chlorophyll content were insignificant. For example, non-significant differences were recorded between the chlorophyll "b" contents at the three irrigation treatments (in both seasons). Also, the chlorophyll "a" and the total chlorophyll ("a" + "b") contents showed no significant increase when the soil moisture level was increased from 50% to 70% F.C. On the other hand, the chlorophyll "a" and the total chlorophyll ("a" + "b") contents were significantly lower at the lowest soil moisture level (irrigation at 30% F.C.), when compared to the values obtained with irrigation at 50 or 70% F.C.

Table (3): Effect of irrigation and nitrogen fertilization treatments on the contents of chlorophyll "a", chlorophyll "b", total chlorophyll (a + b) and carotenoids in *Cynodon dactylon* L. clippings during the 1996/1997 and 1997/1998 seasons.

Fertilization treatments (B)	First season (1997)				Second season (1998)			
	Irrigation (A)			Mean (B)	Irrigation (A)			Mean (B)
	30%	50%	70%		30%	50%	70%	
	Chlorophyll "a" content (mg/g fresh matter)							
Control	1.340	1.376	1.369	1.361	1.332	1.345	1.399	1.358
5 g N/m^2	1.463	1.487	1.504	1.484	1.479	1.435	1.501	1.471
10 g N/m^2	1.670	1.659	1.671	1.666	1.725	1.686	1.673	1.694
15 g N/m^2	1.607	1.625	1.612	1.614	1.487	1.659	1.596	1.580
Mean (A)	1.520	1.536	1.539	---	1.505	1.531	1.542	---
New L.S.D. (0.05) A	0.016				0.016			
B	0.013				0.036			
A X B	0.034				0.070			
	Chlorophyll "b" content (mg/g fresh matter)							
Control	0.453	0.465	0.467	0.461	0.445	0.458	0.461	0.454
5 g N/m^2	0.518	0.534	0.555	0.535	0.519	0.531	0.562	0.537
10 g N/m^2	0.672	0.673	0.670	0.671	0.677	0.681	0.672	0.676
15 g N/m^2	0.672	0.653	0.638	0.654	0.661	0.672	0.622	0.651
Mean (A)	0.578	0.581	0.582	---	0.575	0.585	0.579	---
New L.S.D. (0.05) A	N.S.				N.S.			
B	0.005				0.009			
A X B	0.009				0.018			
	Total chlorophyll content (mg/g fresh matter)							
Control	1.794	1.842	1.838	1.824	1.778	1.803	1.860	1.813
5 g N/m^2	1.982	2.021	2.059	2.020	1.998	1.967	2.064	2.009
10 g N/m^2	2.342	2.332	2.342	2.338	2.402	2.367	2.345	2.371
15 g N/m^2	2.280	2.278	2.251	2.269	2.148	2.333	2.220	2.233
Mean (A)	2.099	2.118	2.122	---	2.081	2.117	2.122	---
New L.S.D. (0.05) A	0.017				0.020			
B	0.016				0.039			
A X B	0.031				0.075			
	Carotenoids content (mg/g fresh matter)							
Control	0.520	0.571	0.582	0.557	0.416	0.470	0.469	0.451
5 g N/m^2	0.658	0.730	0.739	0.709	0.567	0.662	0.678	0.635
10 g N/m^2	0.981	0.982	0.978	0.980	0.976	0.947	0.944	0.955
15 g N/m^2	0.884	0.948	0.903	0.911	0.794	0.826	0.787	0.802
Mean (A)	0.760	0.807	0.800	---	0.688	0.726	0.719	---
New L.S.D. (0.05) A	0.025				0.036			
B	0.026				0.033			
A X B	0.071				0.078			

Regarding the effect of N fertilization on chlorophylls content, data recorded in the two seasons (Table, 3) show that plants receiving the different N fertilization treatments had significantly higher chlorophyll (a, b and total chlorophyll) contents than that of unfertilized control plants in both seasons.Moreover, raising the N fertilization rate from 0 (control) to 5 or 10 g N/m^2 resulted in steady significant increases in the chlorophyll contents. However, a further increase in the N rate from 10 g N/m^2 to the highest level (15 g N/m^2) caused a reduction in the chlorophylls content. Accordingly, the highest values were obtained from the plants fertilized with the medium N rate (10 g N/m^2), followed by those fertilized with the highest rate (15 g N/m^2).

The promotion in the synthesis and accumulation of chlorophyll as a result of chemical N fertilization may be attributed to the role played by nitrogen as an essential component in the structure of porphyrines, which are found in many metabolically active compounds, including chlorophylls. Chlorophylls are bound to, and perhaps even embedded within protein molecules (Devlin, 1975). The favourable effect of fertilization treatments on the chlorophylls content (and consequently the turf colour) is in agreement with the results reported by Christians *et al.* (1981) on *Agrostis palustris*, Nelson and Sosulski (1984) on *Poa pratensis*, Hossni (1993) on *Cynodon dactylon*, Saleh (1993) on ryegrass turf, Goatley *et al.* (1994) on *Cynodon dactylon*, and Soliman (1997) on *Lolium perenne*.

Considerable differences were also detected between the chlorophyll contents in plants receiving the different combinations of irrigation and fertilization treatments. In both seasons, the lowest contents of chlorophyll "a", chlorophyll "b" and total chlorophyll were found in leaves of unfertilized control plants that were irrigated at the lowest soil moisture content (irrigation at 30% F.C.). On the other hand, the highest chlorophyll contents were obtained in plants supplied with the medium N fertilization level (10 g/m^2) and irrigated at 30, 50 or 70% F.C. (with no significant difference between the values resulting from these three treatment combinations).

b. Carotenoids content

Data recorded in the two seasons (Table, 3) show that raising the soil moisture level from 30 to 50% significantly increased the carotenoids content. However, a further increase in the soil moisture content from 50 to 70% F.C. caused a slight (insignificant) reduction in the recorded values. Accordingly, it can be stated that irrigation at the medium soil moisture level (50% F.C.) was the most effective irrigation treatment for promoting the synthesis and accumulation of carotenoids in the leaves of *Cynodon dactylon*, followed by irrigation at the highest soil moisture level (70 % F.C.).

The effect of N fertilization treatments on the carotenoids content (Table 3) was generally similar to their effect on the chlorophyll contents. In both seasons, unfertilized control plants had significantly lower carotenoids contents than those plants supplied with the different fertilization treatments. This favourable effect of N fertilization on the carotenoids content is in agreement with results obtained by Saleh (1993) on ryegrass, and Soliman (1997) on *Lolium perenne*. Also, the recorded values showed a steady increase as the N rate was raised from 0 (control) to 5 or 10 g/m^2, but a further increase in the N rate from 10 to 15 g/m^2 significantly decreased the carotenoids content (compared to that obtained with N fertilization at 10 g/m^2). A similar reduction in the carotenoids content as a result of raising nitrogen levels was reported by Hossni (1993) on *Cynodon dactylon* plants.

As for the interaction between soil moisture and fertilization treatments, data in Table (3) show that within each level of soil moisture (irrigation at 30, 50 and 70% F.C.) the medium rate of N (10 g/m^2) produced plants having the highest carotenoids content, compared to that in plants receiving any other combination treatments. Among the different treatment combinations, combining fertilization using the medium N rate (10 g/m^2) with irrigation at 30, 50 or 70% F.C. gave the highest carotenoids contents (with non-significant differences between these three treatment combinations). In contrast, unfertilized control plants grown at the lowest soil moisture level (irrigation at 30% F.C.) gave the lowest values in both seasons.

3. Carbohydrates (soluble, insoluble sugars, and total carbohydrates) contents in clippings

Chemical analysis of dried clipping samples has shown that the different soil moisture treatments had a significant effect on their carbohydrates (soluble, insoluble and total carbohydrates) contents (Table 4). In both seasons, raising the soil moisture level from irrigation at 30% F.C. to irrigation at 50% or 70% F.C. resulted in a steady decrease in the content of soluble sugars, but increased that of insoluble sugars. In most cases, the values recorded with the different soil moisture levels were significantly different. The only exception to this general trend was detected in the first season, with plants irrigated at 50% F.C. having a soluble sugars content (6.695% of dry weight) that was not significantly different from that of plants irrigated at 70% F.C. (6.640% of dry weight). On the other hand, the effect of soil moisture on the total carbohydrates content differed from one season another. In the first season, irrigation at 30% F.C. gave the highest value, followed by irrigation at 70% (with non-significant differences between the two values), whereas the lowest value was obtained from plants irrigated at 50% F.C. In the second season, however, the total carbohydrates content was increased steadily by raising the soil moisture level, with the highest moisture level (irrigation at 70% F.C.) giving the highest value.

The different fertilization treatments also had a significant effect on the contents of soluble, insoluble and total carbohydrates (Table, 4). In both seasons, the synthesis and accumulation of carbohydrates were generally promoted by N fertilization, with the different N rates giving significantly higher values than those found in unfertilized control plants. Moreover, increasing N fertilization rate from 0 (control) to 5, 10 or 15 g/m^2 resulted in steady increases in the contents of soluble, insoluble and total carbohydrates, with the highest N rate (15 g/m^2) giving significantly higher mean values than those obtained with any other N rate. The favourable effect of the different fertilization treatments on the synthesis and accumulation of carbohydrates may be attributed to the increase in the chlorophylls content of fertilized plants, and to the role played by nitrogen in the structure of porphyrine molecules (as previously mentioned), which are found in the cytochrome enzymes essential for photosynthesis. The increase in the content of chlorophylls and cytochrome enzymes results in an increase in the rate of

Table (4): Effect of irrigation and nitrogen fertilization treatments on the percentage of soluble sugars, insoluble sugars and total carbohydrates in *Cynodon dactylon* L. clippings during the 1996/1997 and 1997/1998 seasons.

Fertilization treatments (B)	Soluble sugars content (% of dry matter)				Insoluble sugars content (% of dry matter)				Total carbohydrates content (% of dry matter)			
	Irrigation (A)			Mean (B)	Irrigation (A)			Mean (B)	Irrigation (A)			Mean (B)
	30%	50%	70%		30%	50%	70%		30%	50%	70%	
First season (1997)												
Control	6.223	5.529	5.294	5.682	7.744	7.894	8.904	8.180	13.966	13.424	14.198	13.862
5 g N/m^2	6.906	6.155	6.099	6.386	8.232	8.536	9.240	8.669	15.139	14.692	15.340	15.057
10 g N/m^2	7.818	6.840	7.037	7.231	8.755	9.186	9.445	9.128	16.573	16.027	16.482	16.360
15 g N/m^2	9.030	8.259	8.132	8.473	9.722	10.007	10.070	9.933	18.753	18.267	18.202	18.407
Mean (A)	7.494	6.695	6.640	---	8.613	8.905	9.414	---	16.107	15.602	16.055	---
New L.S.D. (0.05)												
A	0.143				0.069				0.153			
B	0.132				0.068				0.139			
A X B	N.S.				0.120				0.274			
Second season (1998)												
Control	5.740	5.751	5.652	5.714	7.880	7.927	9.500	8.435	13.620	13.678	15.153	14.150
5 g N/m^2	6.568	6.322	6.526	6.472	9.593	9.519	10.503	9.371	15.162	15.341	17.030	15.844
10 g N/m^2	7.836	7.022	7.040	7.299	9.009	10.992	10.822	10.274	16.846	18.014	17.862	17.574
15 g N/m^2	9.551	8.588	8.011	8.716	9.639	11.729	11.930	11.099	19.191	20.317	19.942	19.816
Mean (A)	7.423	6.920	6.807	---	8.780	9.916	10.688	---	16.204	16.873	17.496	---
New L.S.D. (0.05)												
A	0.093				0.117				0.139			
B	0.113				0.129				0.167			
A X B	0.201				0.226				0.296			

photosynthesis, and a promotion of carbohydrates synthesis and accumulation (Devlin, 1975). The increase in the content of carbohydrates as a result of N fertilization treatments is in agreement with the findings of Hossni (1993) on *Cynodon dactylon*, as well as Saleh (1993) and Soliman (1997) on *Lolium perenne* plants.

Regarding the interaction between soil moisture levels and N fertilization rates, data presented in Table (4) show that the various treatment combinations had different effects on the different types of carbohydrates. For example, the highest soluble sugars content (in both seasons) was found in plants fertilized with the highest N rate (15 g/m^2) and grown at the lowest soil moisture level (irrigation at 30% F.C.), whereas the highest insoluble sugars content was obtained from plants fertilized with the same N rate (15 g/m^2) but grown at the highest soil moisture level (irrigation at 70% F.C.). Also, the lowest soluble sugars content (in both seasons) was obtained from unfertilized control plants grown under the highest soil moisture level (irrigation at 70% F.C.), whereas the lowest insoluble sugars content was found in unfertilized plants that were grown under the lowest soil moisture level (irrigation at 30% F.C.). On the other hand, the effect of the different treatment combinations on total carbohydrates content varied slightly from one season to another. In the first season, the highest total carbohydrates content was obtained in plants grown at the lowest soil moisture level (irrigation at 30% F.C.) and fertilized with the highest N rate (15 g/m^2), whereas the lowest value was obtained in unfertilized control plants grown at the medium soil moisture level (irrigation at 50% F.C.). In the second season, however, the highest value was obtained in plants grown at the medium soil moisture level (irrigation at 50% F.C.) and fertilized with the highest N rate (15 g/m^2), whereas the lowest value was obtained in unfertilized control plants grown at the lowest soil moisture level (irrigation at 30% F.C.).

4. Nutrient contents

a. Nitrogen

Data in Table (5) show that the nitrogen content in Bermudagrass was significantly affected by soil moisture levels. In both seasons, plants grown under the low soil moisture level (irrigation at 30% F.C.) had the highest N percentages, followed by plants grown under the highest soil moisture level (irrigation at 70% F.C.), whereas plants grown at the medium soil moisture level (irrigation at 50%) gave the lowest values. However, the differences between values recorded with the medium and high soil moisture levels (irrigation at 50 or 70% F.C.) were insignificant in both seasons.

The N content was also significantly affected by the N fertilization treatments. In both seasons, unfertilized control plants had significantly lower N contents than those receiving the different N fertilization rates. Similar increases in the N content of plants receiving N fertilization have been reported by Anstett (1981) on some turfs, Hossni (1993) on *Cynodon dactylon*, and Saleh (1993) and Soliman (1997) on *Lolium perenne*. Among the tested N rates, the highest one (15 g N/m^2) gave the highest value in the first season, whereas the medium rate (10 g N/m^2) gave the highest value in the second season. On the other hand, the least effective N rate in both seasons, in terms of increasing the N content, was the lowest rate (5 g N/m^2). The superior effect of relatively high N concentrations (10 or 15 g N/m^2) on increasing N absorption and assimilation, compared to that of lower N rates, is in agreement with the findings of Boonduang *et al.* (1976) on *Cynodon dactylon*, Leyer and Skirde (1980) on *Lolium perenne* and *Poa pratensis*, and Leyer (1980) on a turfgrass consisting of *Lolium perenne*, *Poa pratensis* cv. Pac. and *P. pratensis* cv. Kimono.

Regarding the interaction between the soil moisture and fertilization treatments on the N content, the data presented in Table (5) show that the recorded results differed from one season to another. In the first season, the interaction between these two factors was insignificant, with unfertilized control plants grown under the medium soil moisture level (irrigation at 50% F.C.) giving the lowest value, whereas plants supplied with the highest N rate (15 g/m^2) and grown under the highest soil moisture level (irrigation at 70% F.C.) had the highest N content, followed by plants supplied with 10 g N/m^2 and grown under the lowest soil moisture level (irrigation at 30% F.C.). On the other hand, a significant interaction was detected in the second season between the soil moisture levels and N fertilization rates on the N content. As in the first season, the lowest value in the second season was obtained from unfertilized control plants grown under the medium soil moisture level (irrigation at 50% F.C.). However, the highest value in the second season was found in plants fertilized with 15 g N/m^2 and grown under the lowest soil moisture level (irrigation at 30% F.C.). Non-significant difference was detected in the second season between the N content in these plants and that found in plants grown under the same soil moisture level (30% F.C.) and supplied with lower N rates (5 or 10 g/m^2), or plants grown at the highest soil moisture level (irrigation at 70% F.C.) and fertilized with 10 g N/m^2.

b. Phosphorus

The results recorded in the two seasons (Table, 5) show that the P content in clippings was steadily increased by increasing the soil moisture content. Accordingly, the highest P content was found in plants irrigated at 70% F.C., which gave significantly higher values than those obtained from plants irrigated at 30 or 50% F.C.

The data in Table (5) show also that the P content was significantly increased by the different N fertilization treatments, compared to the control (in both seasons). Moreover, raising the N application rate to 5 or 10 g/m^2 resulted in steady significant increases in the recorded values. However, a further increase in the N rate from 10 to 15 g/m^2 caused a slight (insignificant) decrease in the P content. The increase in the P content as a result of applying the different fertilization treatments is in agreement with the results obtained by Abdalla (1966) and Goatley *et al.* (1994) on *Cynodon dactylon*, and Soliman (1997) on *Lolium perenne*.

Non-significant interactions were detected between the soil moisture and N fertilization on the P content in clippings. In both seasons, the lowest P content was found in unfertilized control plants grown under the lowest soil moisture content (irrigation at 30% F.C.), whereas the highest value was

Table (5): Effect of irrigation and nitrogen fertilization treatments on the nitrogen, phosphorus and potassium percentages in *Cynodon dactylon* L. clippings during the 1996/1997 and 1997/1998 seasons.

Fertilization treatments (B)	N content (% of dry matter) Irrigation (A) 30%	50%	70%	Mean (B)	P content (% of dry matter) Irrigation (A) 30%	50%	70%	Mean (B)	K content (% of dry matter) Irrigation (A) 30%	50%	70%	Mean (B)
First season (1997)												
Control	1.710	1.350	1.470	1.510	0.570	0.590	0.630	0.596	2.000	2.500	2.000	2.166
5 g N/m^2	1.930	1.870	1.910	1.903	0.660	0.710	0.750	0.706	2.370	2.370	2.120	2.286
10 g N/m^2	2.210	1.990	2.040	2.080	0.780	0.850	0.970	0.866	2.500	2.620	2.370	2.496
15 g N/m^2	2.170	1.880	2.230	2.093	0.740	0.820	0.900	0.820	2.480	2.580	2.340	2.466
Mean (A)	2.005	1.772	1.912	---	0.687	0.742	0.812		2.337	2.517	2.207	
New L.S.D. (0.05) A	0.181				0.054				0.128			
B	0.144				0.084				0.109			
A X B	N.S.				N.S.				0.224			
Second season (1998)												
Control	1.600	1.210	1.240	1.350	0.560	0.590	0.620	0.590	2.210	2.250	2.120	2.163
5 g N/m^2	2.050	1.380	1.280	1.570	0.660	0.650	0.710	0.673	2.370	2.500	2.170	2.346
10 g N/m^2	2.320	1.650	2.010	1.993	0.710	0.800	0.910	0.806	2.620	2.750	2.500	2.623
15 g N/m^2	2.250	1.560	1.510	1.773	0.680	0.760	0.870	0.770	2.580	2.710	2.460	2.583
Mean (A)	2.055	1.450	1.510	---	0.652	0.700	0.777		2.422	2.552	2.312	
New L.S.D. (0.05) A	0.085				0.056				0.139			
B	0.160				0.066				0.088			
A X B	0.359				N.S.				N.S.			

obtained from plants fertilized with 10 g N/m^2 and grown under the highest soil moisture level (irrigation at 70% F.C.).

c. Potassium

Chemical analysis of dried Bermudagrass samples has revealed that the soil moisture level had a significant effect on the K content. In both seasons, plants grown under the medium soil moisture level (irrigation at 50% F.C.) had the highest K content, followed by plants grown under the lowest soil moisture level (irrigation at 30% F.C.), with non-significant differences between values obtained for the two soil moisture levels. On the other hand, increasing the soil moisture content to the highest level (irrigation at 70% F.C.) resulted in lower K percentages, compared to values obtained at lower soil moisture levels (irrigation at 30 or 50% F.C.).

The K content was also affected significantly by the different N fertilization treatments (Table 5). In both seasons, unfertilized control plants had significantly lower K contents than those fertilized with any of the tested N rates. Moreover, the K content was steadily increased by raising the N rate up to the medium rate (10 g/m^2) which gave the highest values in both seasons. Increasing the N rate from 10 to 15 g/m^2 resulted in a slight (insignificant) decrease in the K content. Similar results were reported by Hossni (1993) and Goatley *et al.* (1994) on *Cynodon dactylon*, and Soliman (1997) on *Lolium perenne*.

A significant interaction was detected in the first season between the soil moisture levels and the N fertilization treatments on the K content, with the unfertilized plants grown under low or high moisture levels (i.e. irrigation at 30 or 70% F.C.) having the lowest K content, whereas the highest value was obtained from plants supplied with the medium N rate (10 g/m^2) and grown under the medium soil moisture level (irrigation at 50% F.C.). The results recoded in the second season followed an almost similar trend, but the interaction was insignificant.

CONCLUSION

From the above results, it can be concluded that for the best vegetative growth of Bermudagrass (*Cynodon dactylon* L.), the soil moisture content should not be allowed to drop below 70% F.C., and the plants should be fertilized with 15 g N/m^2/month, as this resulted in the most vigorous vegetative growth (in terms of plant height, as well as the fresh and dry weight of clippings). However, turf colour was more sensitive to the N rate than to the soil moisture level (within the tested range of soil moisture levels), since the best colour (i.e. the highest leaf pigments content) was obtained with fertilization using a moderate N rate (10 g/m^2), regardless of the soil moisture level.

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تأثير رطوبة التربة و التسميد النتروجينى على النمو الخضرى و التركيب الكيميائى لنجيل البرمودا (*Cynodon dactylon* L.)

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أجريت هذه الدراسة بحقل التجارب بقسم بساتين الزينة بكلية الزراعة، جامعة القاهرة، الجيزة، خلال الموسمين المتتاليين ١٩٩٧/١٩٩٦ و ١٩٩٨/١٩٩٧، بهدف بحث تأثير محتوى الرطوبة بالتربة (الرى عند وصول محتوى الرطوبة إلى ٣٠%، ٥٠% أو ٧٠% من السعة الحقلية)، و مستوى التسميد النيتروجينى [صفر، ٥، ١٠ أو ١٥ جم نيتروجين/م^{٢}، مضافة شهرياً فى صورة كبريتات الأمونيوم (٢٠,٥% نيتروجين)] على النمو الخضرى و التركيب الكيميائى لنجيل البرمودا (*Cynodon dactylon* L.). هذا و قد أجريت معاملات الرى بإضافة ٢٥ لتر من ماء الصنبور/م^{٢}/رية. هذا و أدى الجمع بين الرى عند وصول محتوى الرطوبة إلى ٧٠% من السعة الحقلية، و التسميد بمعدل مرتفع نسبياً من النيتروجين (١٥ جم/م^{٢}) إلى أقوى نمو خضرى (من حيث إرتفاع النبات، و الأوزان الطازجة و الجافة لناتج القص)، إلا أن لون المسطح كان أكثر حساسية لمعدل النيتروجين المضاف عنه لمستوى الرطوبة فى التربة (وذلك فى حدود المدى الذى تم تجربته من مستويات رطوبة التربة)، حيث تم الحصول على أفضل لون للمسطح (أعلى محتوى من الصبغات الخضراء فى الأوراق) عند التسميد بمعدل متوسط من النيتروجين (١٠ جم/م^{٢}) بصرف النظر عن محتوى الرطوبة فى التربة. رفع محتوى الرطوبة فى التربة أدى إلى نقص مطرد فى محتوى السكريات الذائبة، إلا أنه زاد تركيز السكريات غير الذائبة فى ناتج القص. كذلك فإن محتويات السكريات الذائبة و غير الذائبة و الكربوهيدرات الكلية زادت طردياً بزيادة معدل التسميد النيتروجينى، حيث أعطى أعلى معدل نيتروجين (١٥ جم/م^{٢}) أعلى القيم. و فى أغلب الحالات تم الحصول على أعلى المحتويات من العناصر الغذائية (نيتروجين و فوسفور و بوتاسيوم) فى النباتات المسمدة بالمعدل المتوسط من النيتروجين (١٠جم/م^{٢}). أما تأثير محتوى الرطوبة فى التربة على محتوى العناصر الغذائية فقد إختلف من عنصر إلى آخر، حيث تم الحصول على أعلى تركيزات متوسطة للنيتروجين و الفوسفور و البوتاسيوم فى النباتات المروية عند ٣٠% و ٧٠% و ٥٠% من السعة الحقلية، على التوالى.